

Coordinated Science Campaign Scheduling for Sensor Webs

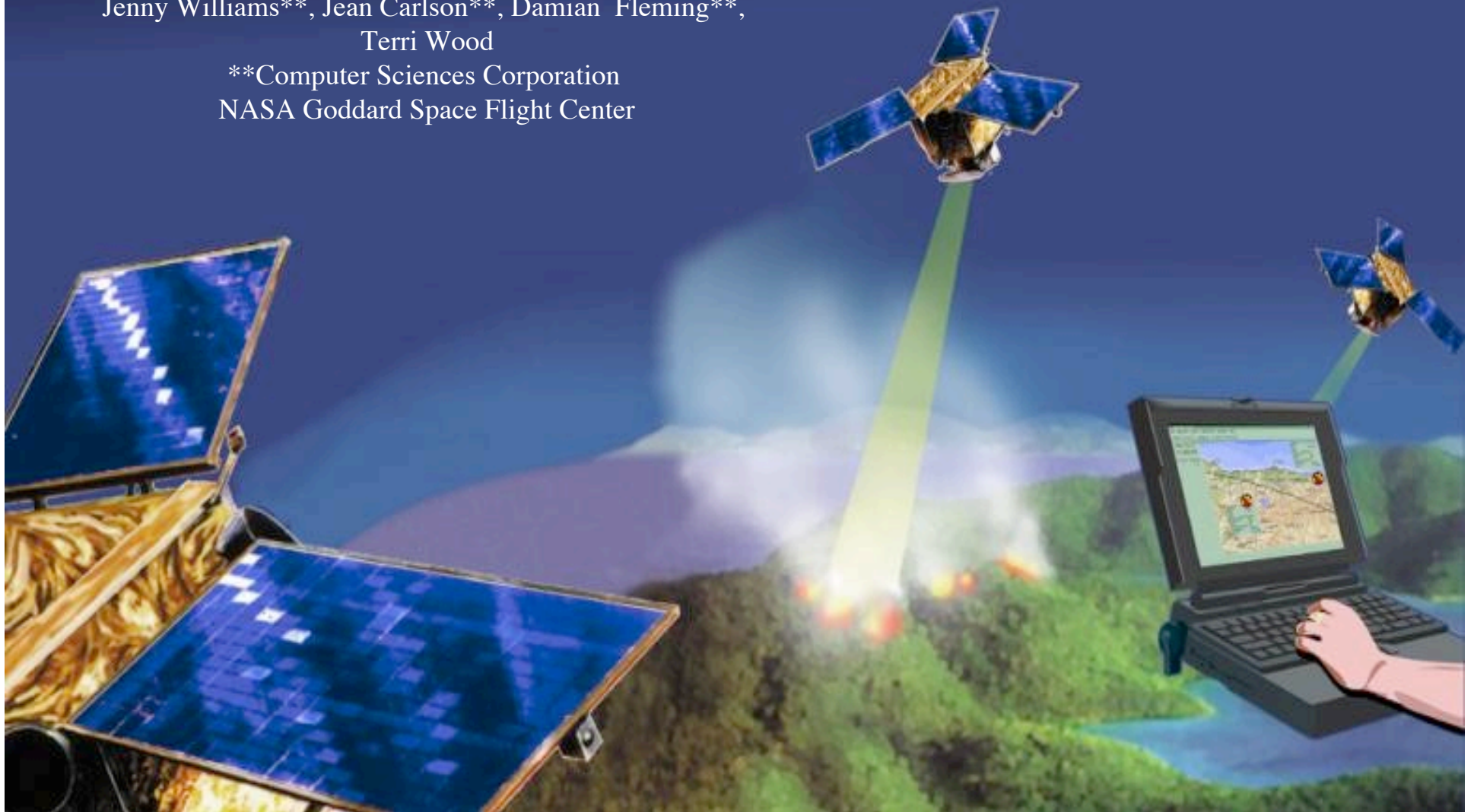
Robert Morris, Jennifer Dungan, Will Edgington*

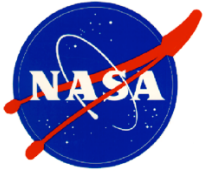
*QSS Group Inc

NASA Ames Research Center

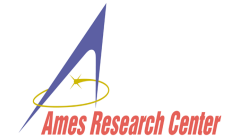
Jenny Williams**, Jean Carlson**, Damian Fleming**,
Terri Wood

**Computer Sciences Corporation
NASA Goddard Space Flight Center

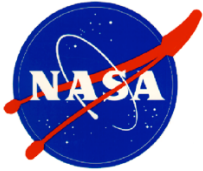




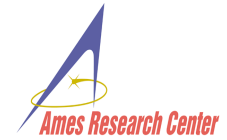
OUTLINE



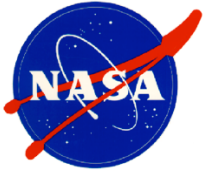
- Problem Statement
- Statement of goals and objectives
- Description of technology
 - Architecture
 - Approach to coordinated observing
- DESOPS System description
 - Using DESOPS
 - System status
- Future goals and challenges



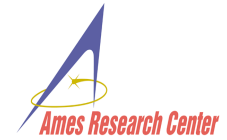
Linking Observations and Models



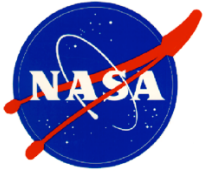
- NASA's Earth science planning emphasizes maintaining a close linkage between observations and models so that the benefits of both sets of activities are maximized.
 - Space-based
 - Sub-orbital
- It is important to recognize the linkage between different types of observations, especially in the context of
 - validation of space-based observations
 - coordinated deployment of satellite, airborne, balloon, and/or ground-based measurements in process-oriented field campaigns.



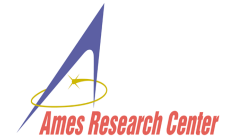
Vision: Model-based Observing



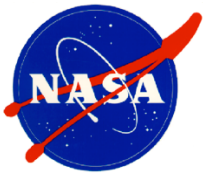
- Harnessing a large number of heterogeneous, distributed sensing resources.
- Enable users to seamlessly access these resources for scientific goals.
- These goals can be viewed as complex workflows, consisting of a series of data acquisitions and transformations.
- Workflow generation can be viewed as a planning problem.
 - Data products as planning goals.
 - Plan as sequences of operations to accomplish the goals.
- Akin to “grid computing” idea.



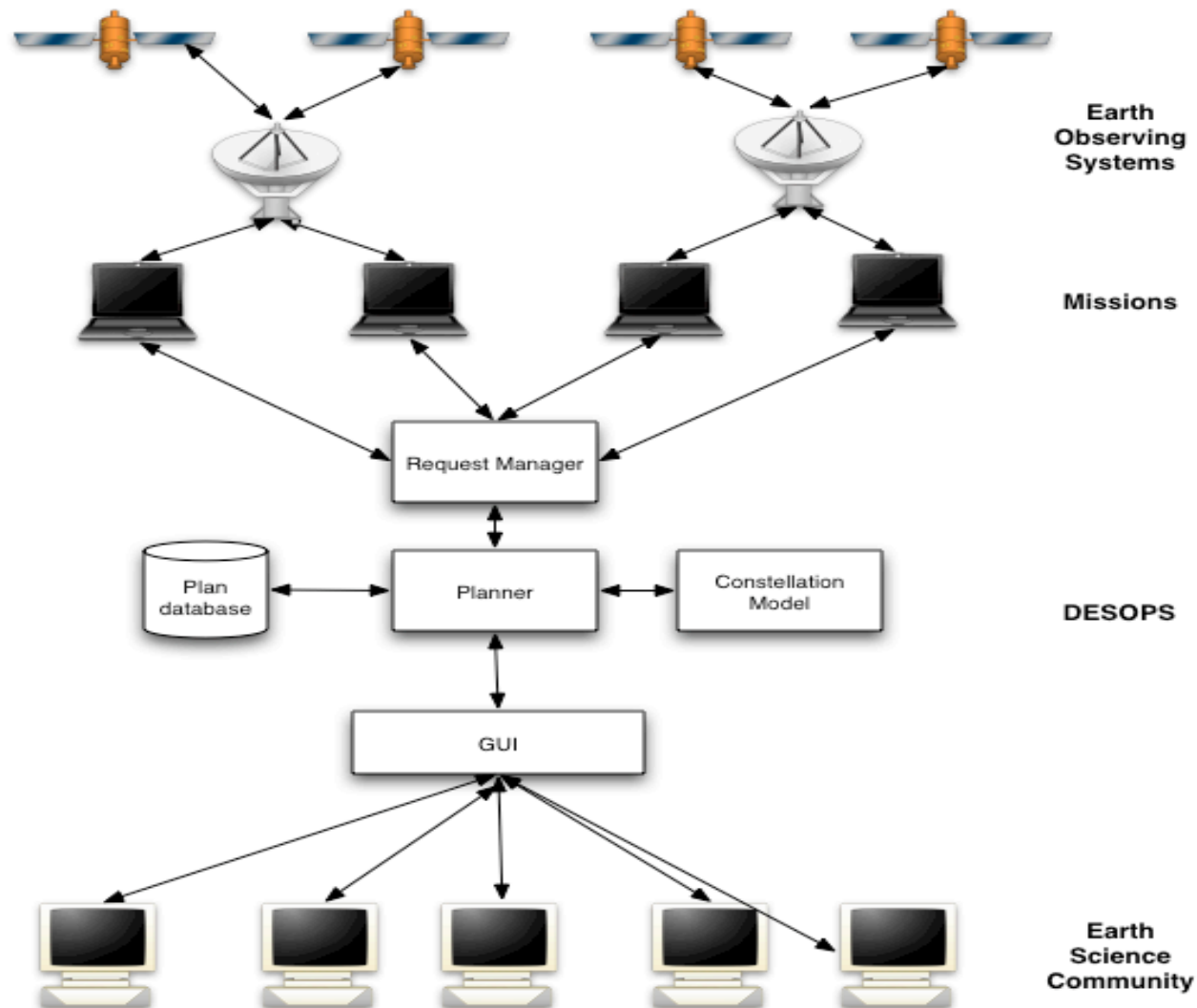
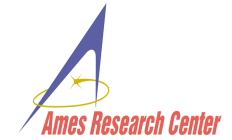
Goal and Objective of Research

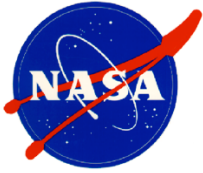


- **Goal:** Establish a tighter link between users of remote sensing resources and the resources themselves.
 - More efficient use of resources
 - Better science return
- **Objective:** Develop an software infrastructure for coordinated observations.
 - Provides a single information portal into daily mission observation scheduling operations.
 - Integrated tool for constructing and executing a set of requests to Earth observing missions.

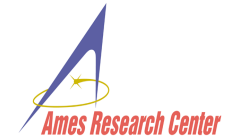


Coordinated Observation Scheduling Architecture

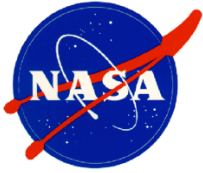




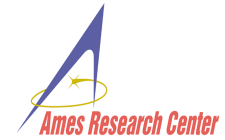
DESOPS System Components



- Plan database
 - Stores campaign constraints, plan, state.
- Planner
 - Manages temporal plan construction interactively with user.
- Constellation model
 - Defines the observation resources available to build campaigns.
 - Models satellite orbit dynamics
- Request manager
 - Formats and submits requests to missions
 - Monitors state of campaign
 - Initiates replanning activities
- User interface
 - Displays campaign information
 - Allows interactive input



Earth Science Campaign as Planning Problem

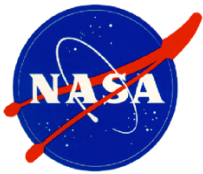


A coordinated effort to collect a series of satellite measurements towards a science goal

Each measurement consists of

- A sensor capability
- A location on the Earth
- A desired time window
- Other constraints

Exogenous events (fires, hurricanes, etc.)



Example campaign



Goal: Validate an emissions model predicting the aerosols released by wildfires.

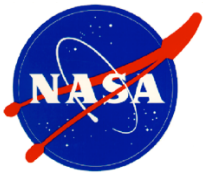
Measurements required or desired:

- Vegetation type/biomass (required)
- Fuel moisture content (desired)
- Fire temperature (required)
- Aerosol concentration (required)
- Burned area (required)

Location: San Diego County

Requested Times:

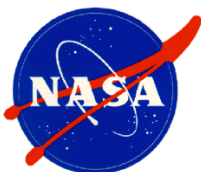
- Vegetation type/biomass --> priori to fire (summer)
- Fuel moisture content --> just prior to fire
- Fire temperature --> coincident to fire
- Aerosol concentration --> coincident to fire
- Burned area --> after fire



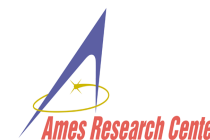
Available Sensors



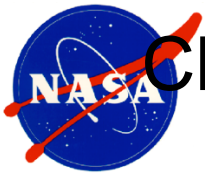
ETM+ or TM (Landsat) -- vegetation type, June or July
Hyperion (EO-1) -- moisture content, just preceeding the fire
MODIS (Aqua) -- aerosol concentration, coincident to fire, pm
MODIS (Terra) -- aerosol concentration, coincident to fire, am
MOPITT (Terra) -- aerosol concentration, coincident to fire, am
ASTER (Terra) or TM (Landsat) -- fine spatial resolution burned area, post-fire
MODIS (Terra) -- coarse spatial resolution burned area, post-fire, am
MODIS (Aqua) -- coarse spatial resolution burned area, post-fire, pm



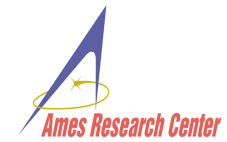
Data prices



Sensor	Pre-acquisition cost	Archived data cost
Landsat ETM+	\$800	\$800
Landsat TM	\$625	\$625
ASTER	\$55	\$55
Hyperion	\$1500 (42 km) \$2500 (185 km)	\$250
MODIS	\$0	\$0
MOPPIT	\$0	\$0



Characteristics of observation scheduling problem



Reasoning under uncertainty

Observations typically surround a natural event (fires, volcanos, tsunamis)

Missions control resource, are “uncooperative”

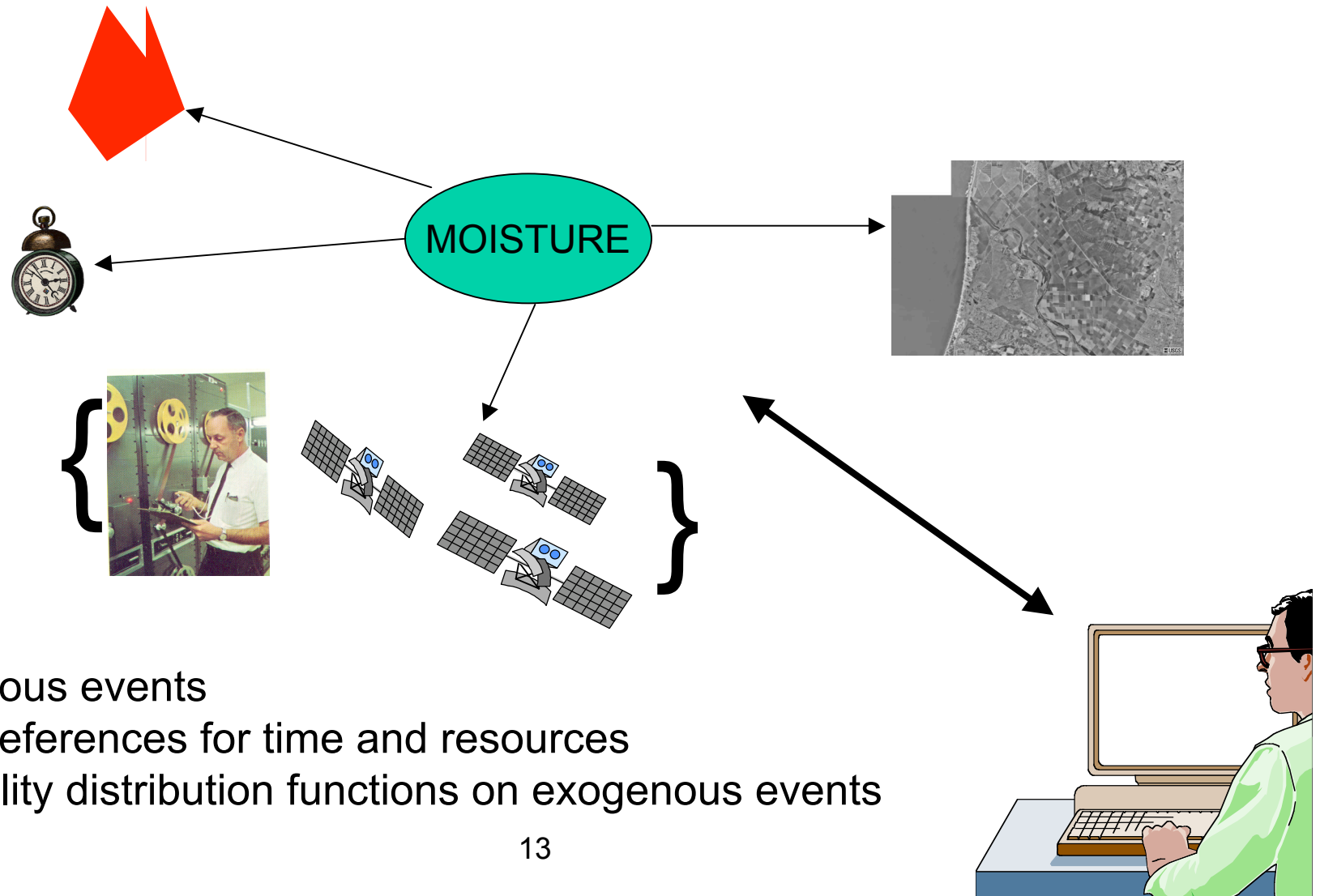
Multi-criteria optimization

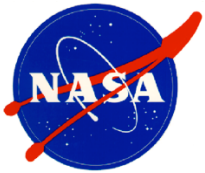
Users express preferences for sensors, time of observation, cost

Result: approach that combines flexible planning with continuous re-scheduling

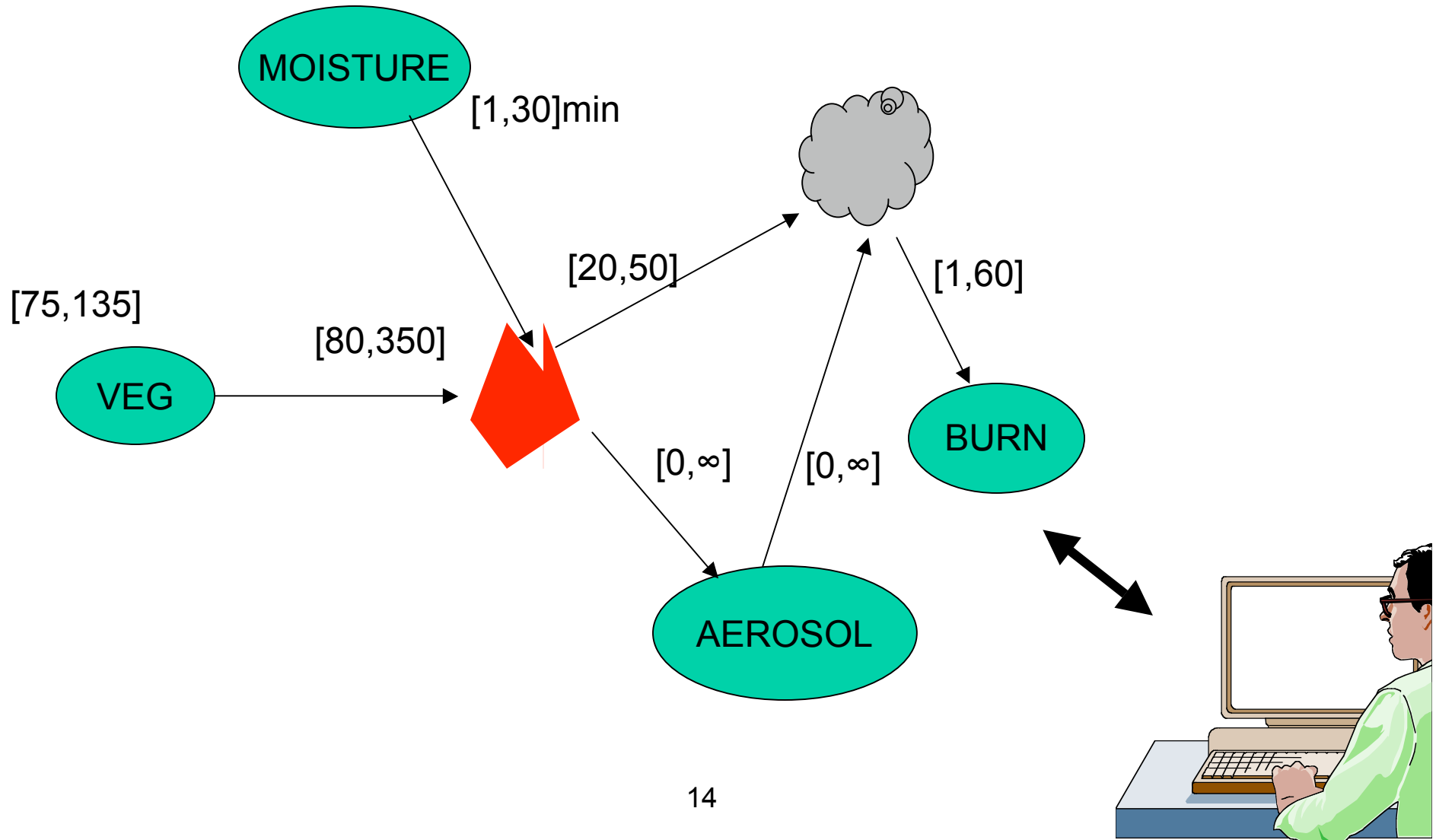
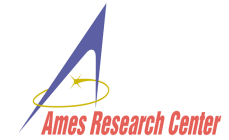


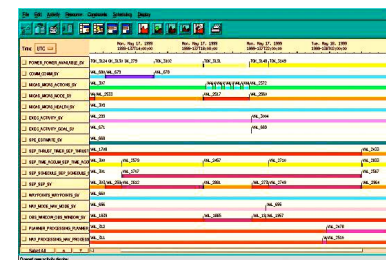
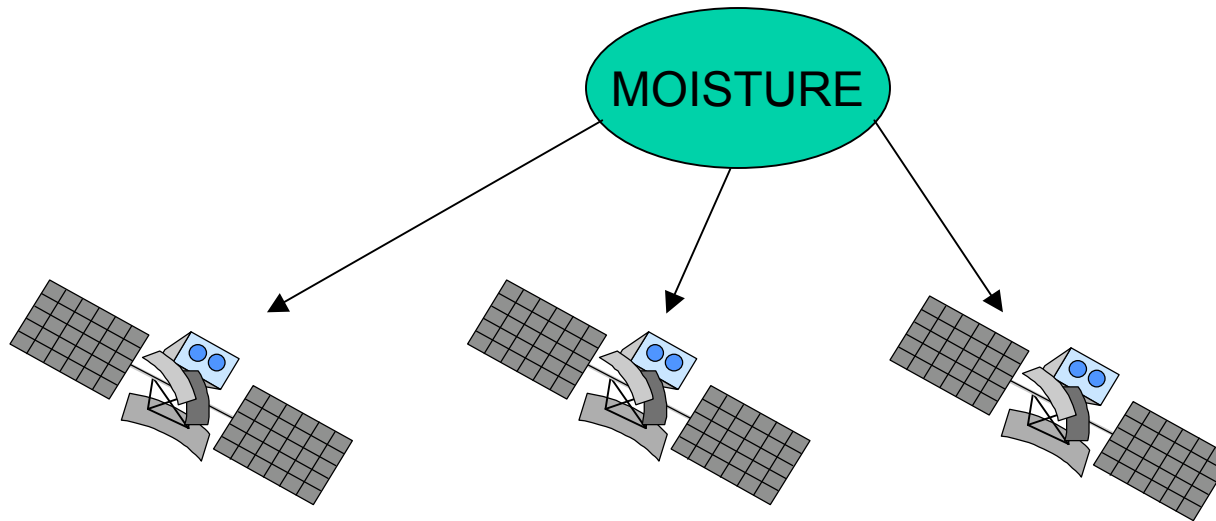
1. Define a set of Measurements and Associated Constraints

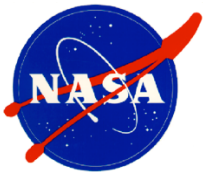




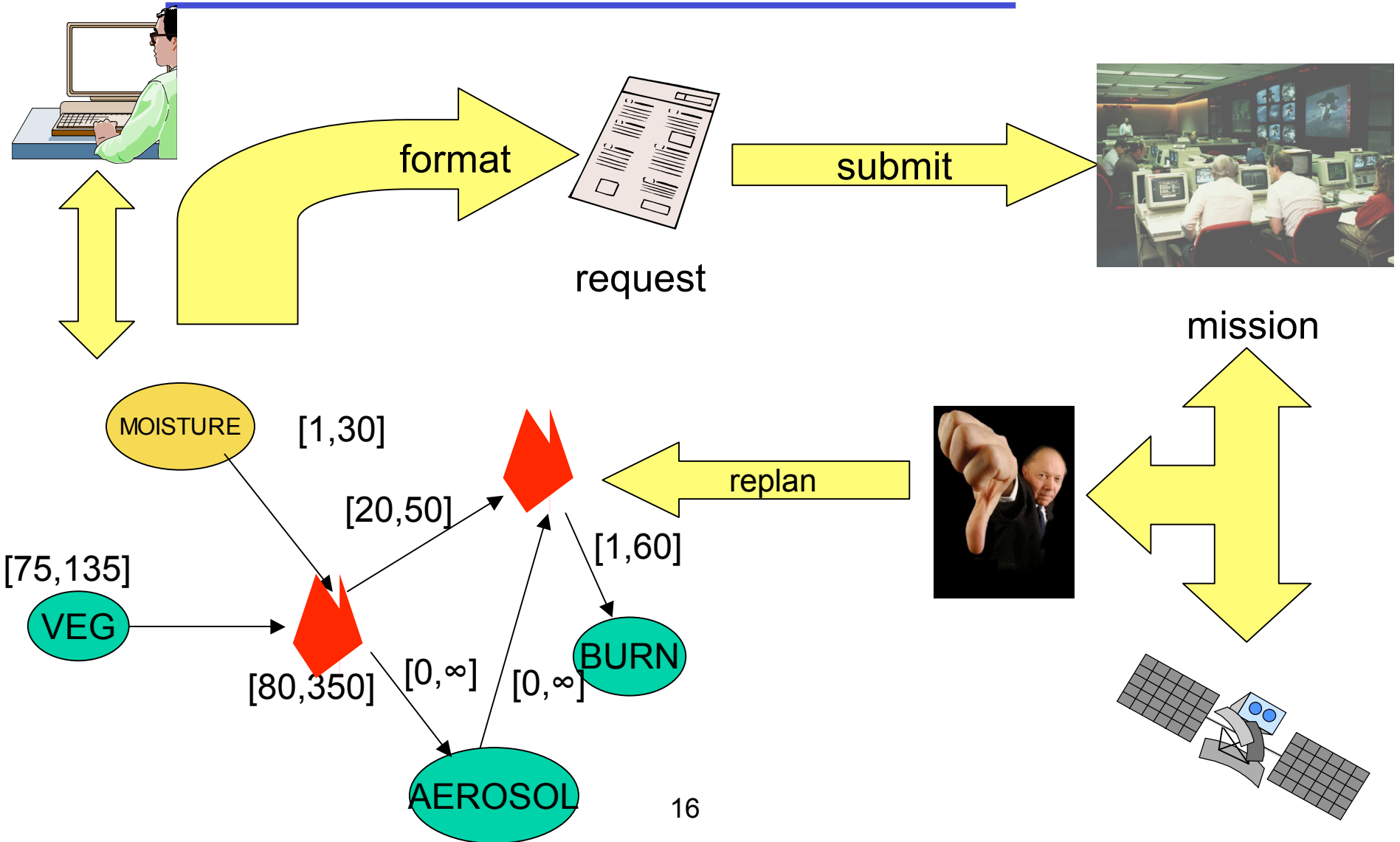
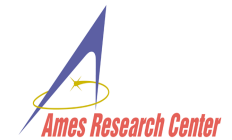
2. Build Flexible Temporal Plan For Campaign

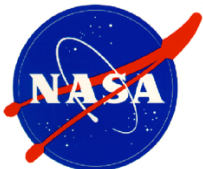






4. Dispatch Flexible Plan, Monitor, Replan





DESOPS User Interface



Campaign

File Campaigns AOI Constellation Model Help Simulation

1:6,250,000

Lat, Lon (35.872, -113.62) - x, y (496,100)

DESOPS

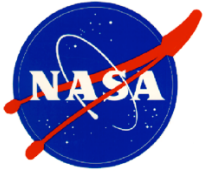
- [-] Campaigns
 - [+] Demo Campaign
 - [+] Fire Scenario
 - [+] TLVVCampaign
 - [+] Test example 1
 - [+] Test example 2
 - [-] Test example 3
 - [-] Campaign Requests
 - Measurement 1 for test 3
 - Measurement 2 for test 3
 - Measurement 3 for test 3
 - [+] Events
 - [-] Test scenario 4
 - [+] Campaign Requests
 - [+] Events
 - [+] AOIs

Flexible plan for Test example 3

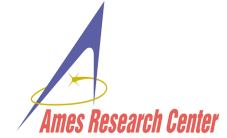
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graph TD; A([Plan for Measurement]) -- "[0,365]" --> D([mudslide0317]); B([Plan for Measurement]) -- "[1,30]" --> D; D -- "[1,30]" --> C([Plan for Measurement])
```

start

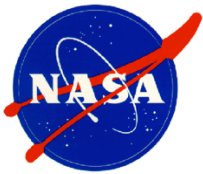
11:25 AM



Summary of Technical Accomplishments



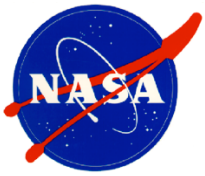
- Developed Architectural Components and Communication Protocol for directly linking Science Pis more with observing resources
 - Enabling coordination with minimal disruption to current mission practices
 - Based loosely on “computational grid” paradigm
- Generalization of approaches to temporal planning and execution
 - Temporal planning with preferences
 - Representing temporal uncertainty
- Implemented prototype of architecture
 - Testing end-to-end capabilities in simulation



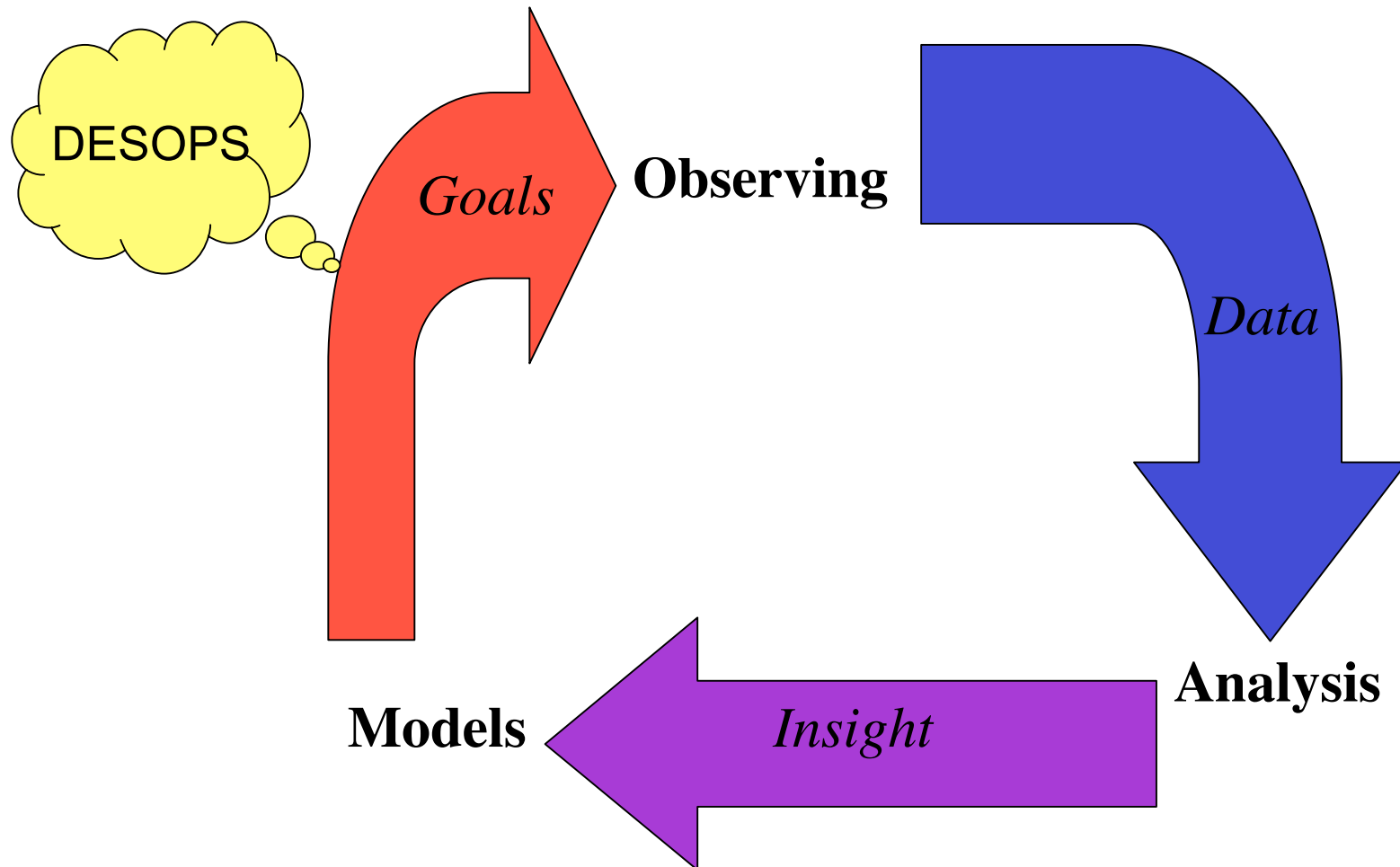
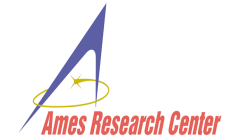
Future Challenges

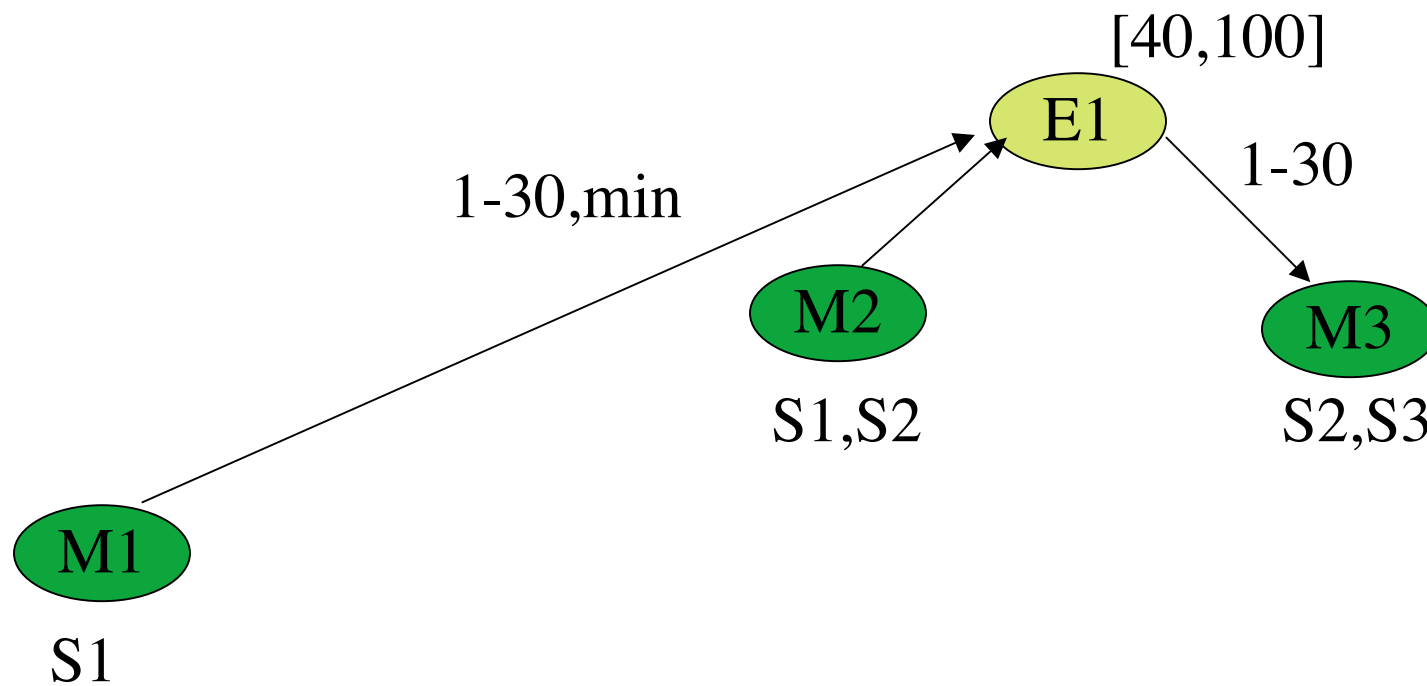
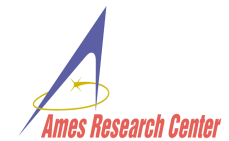
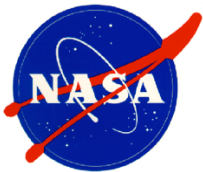


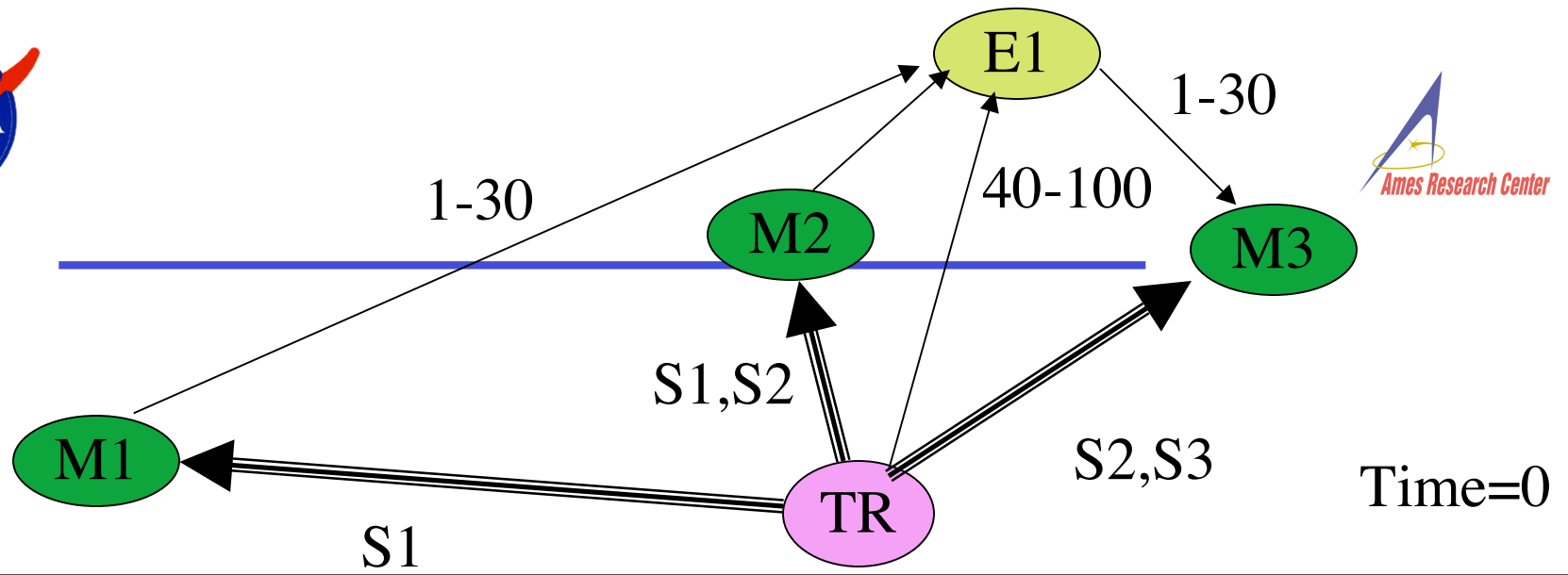
- Integration of Earth Science Models into Observation Scheduling
 - Models assist users in formulating optimal campaigns for observation
- “Closing the loop” between observation scheduling and data analysis
 - Results of analysis trigger new observation goals
- Expand scope of planning
 - Goal of planning is acquisition of data products
- Expand to missions that coordinate satellite-based with sub-orbital observations.



One part of the IT role in the Earth Science Vision

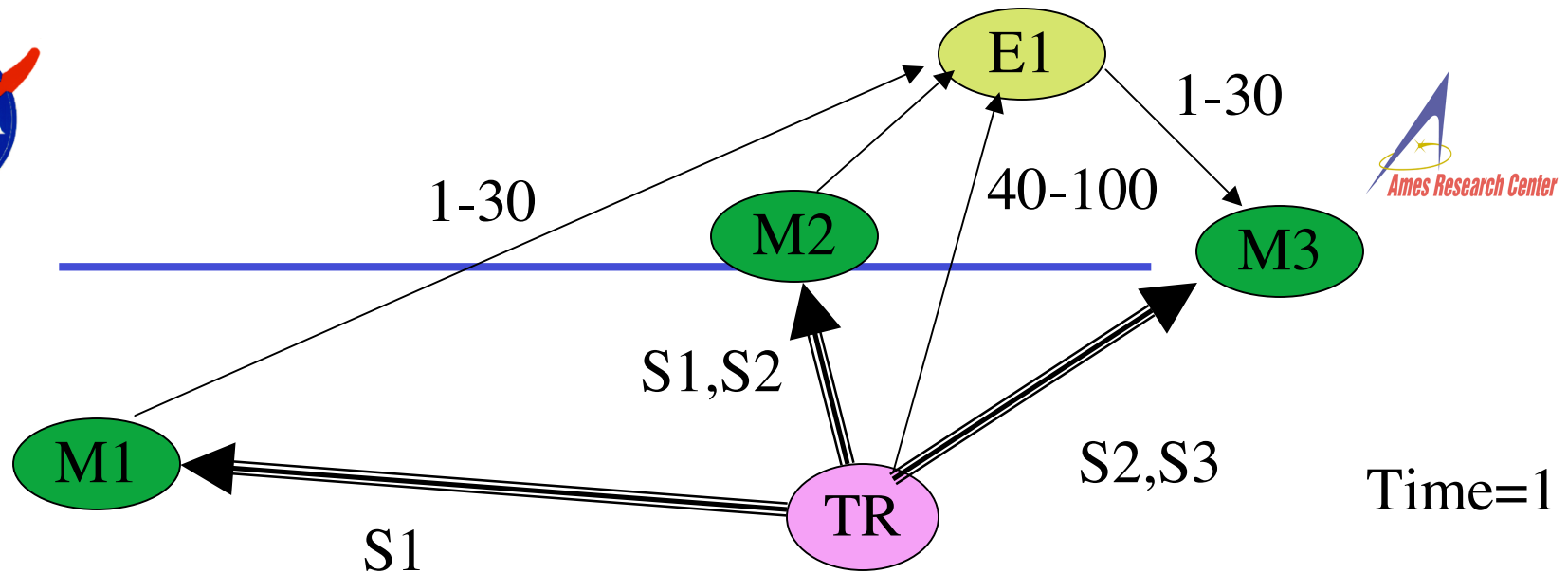






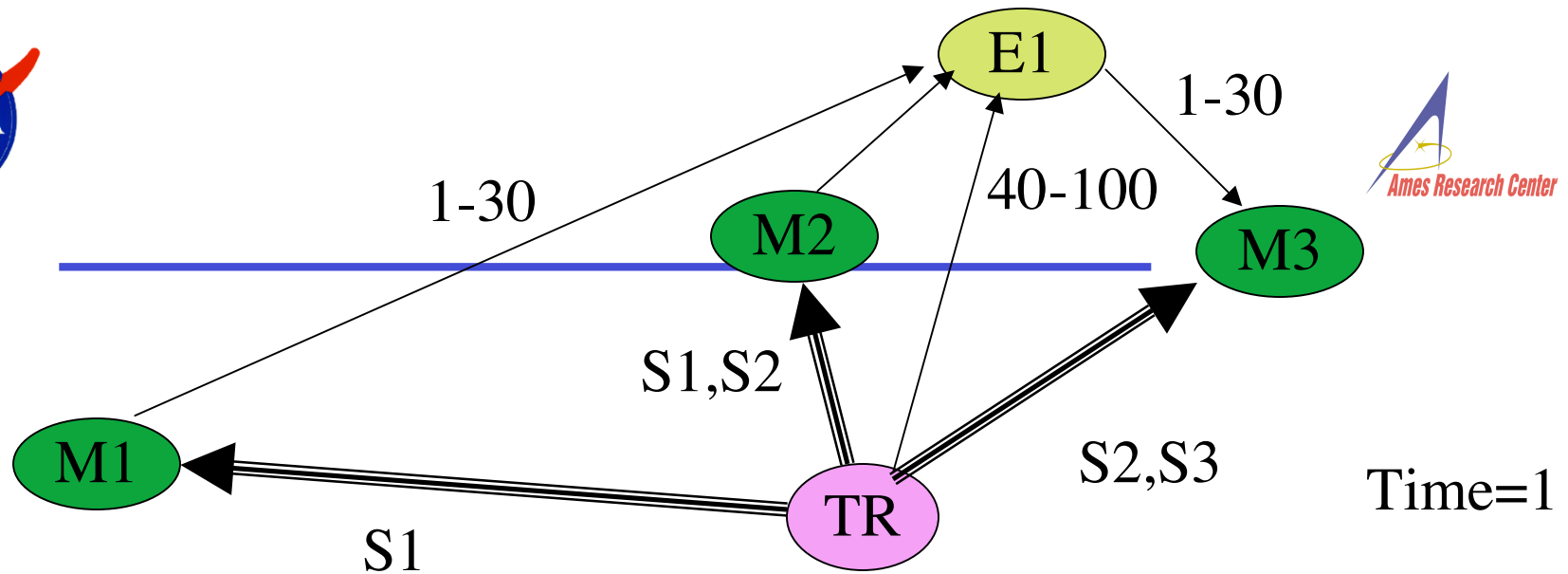
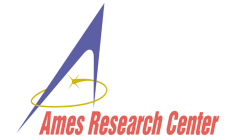
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M1	S1	40	Init
M1	S1	57	Init
M2	S1	60	Init
M3	S2	50	Init
M3	S3	100	Init
M3	S3	120	Init

Observation Request Table



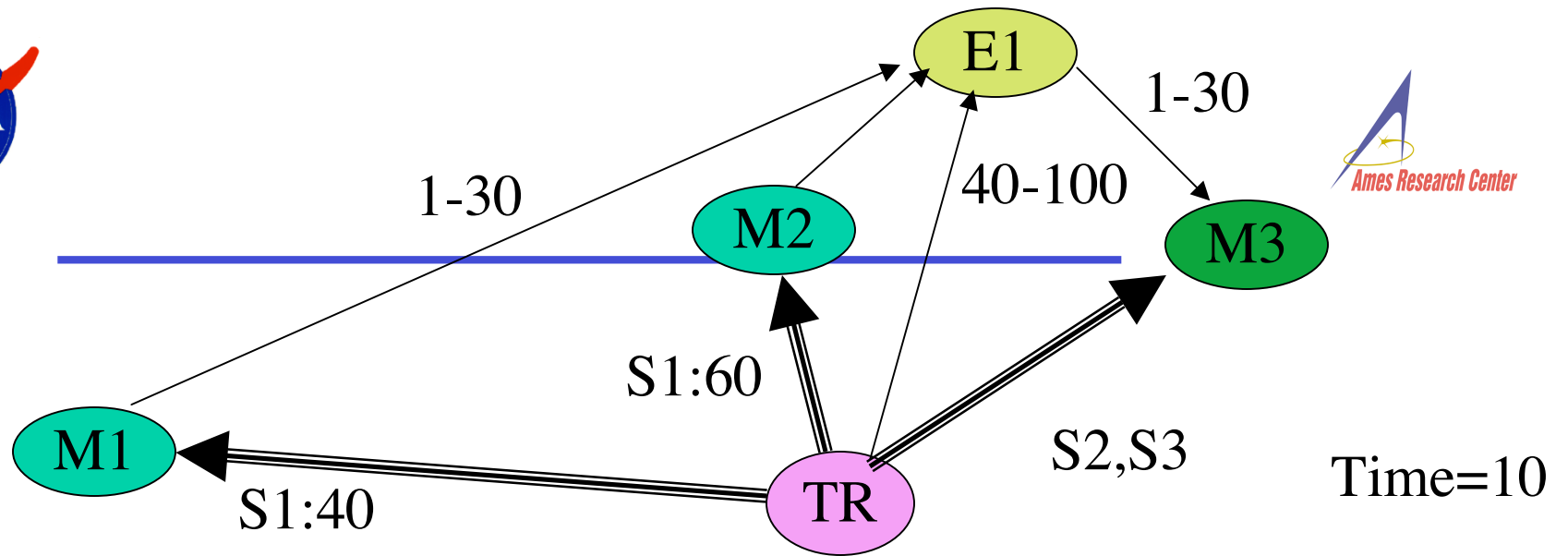
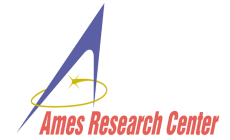
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M2	S1	60	<u>Submitted</u>
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M3	S3	120	Init

Observation Request Table



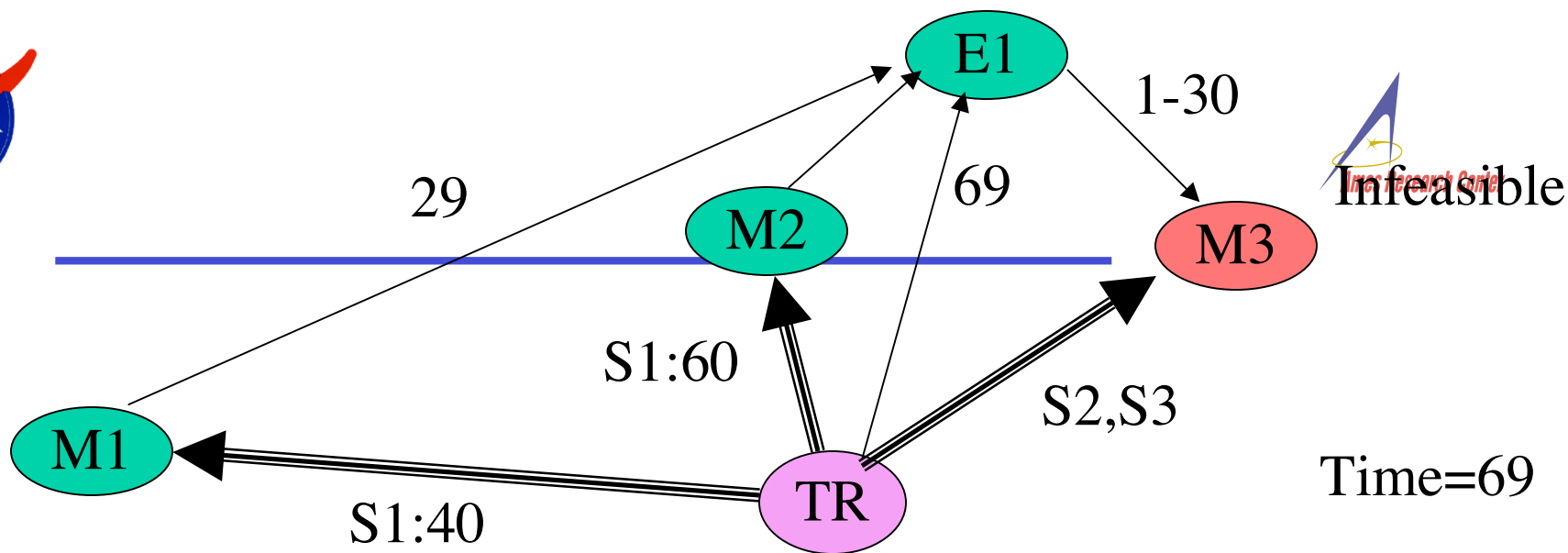
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M2	S1	60	<u>Submitted</u>
M3	S2	50	Init
M3	S3	100	<u>Closed (user)</u>
M3	S3	120	Init

Observation Request Table



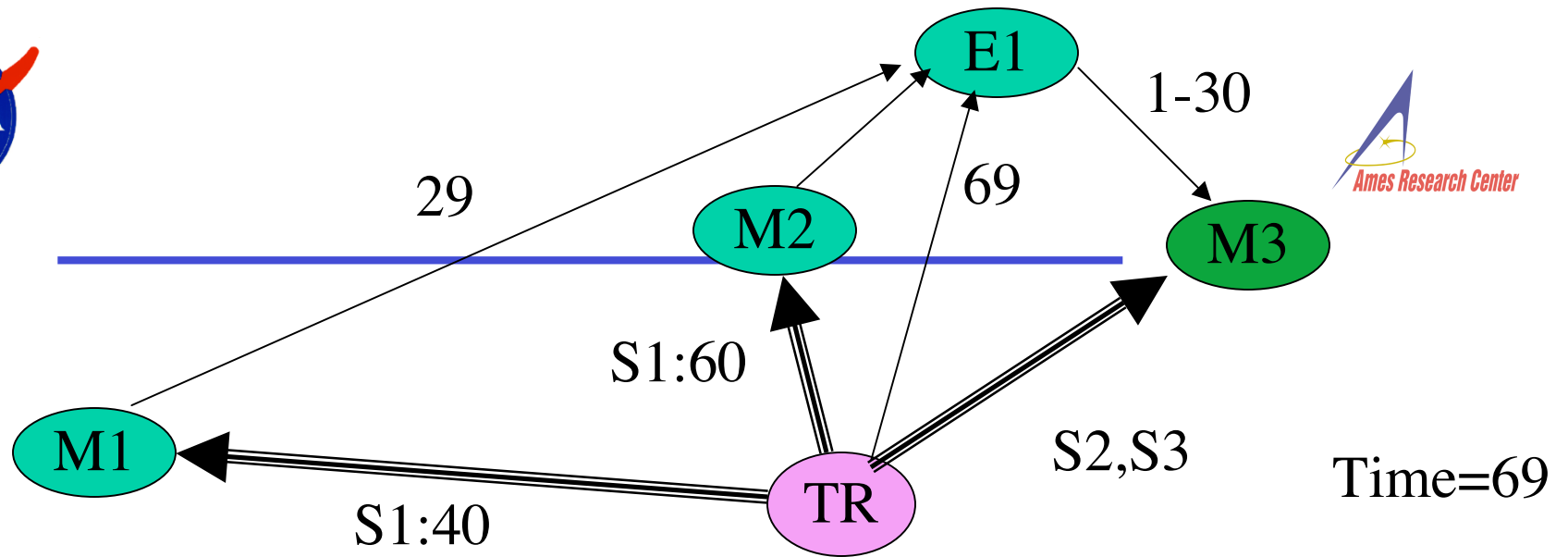
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M1	S1	57	<u>Open</u>
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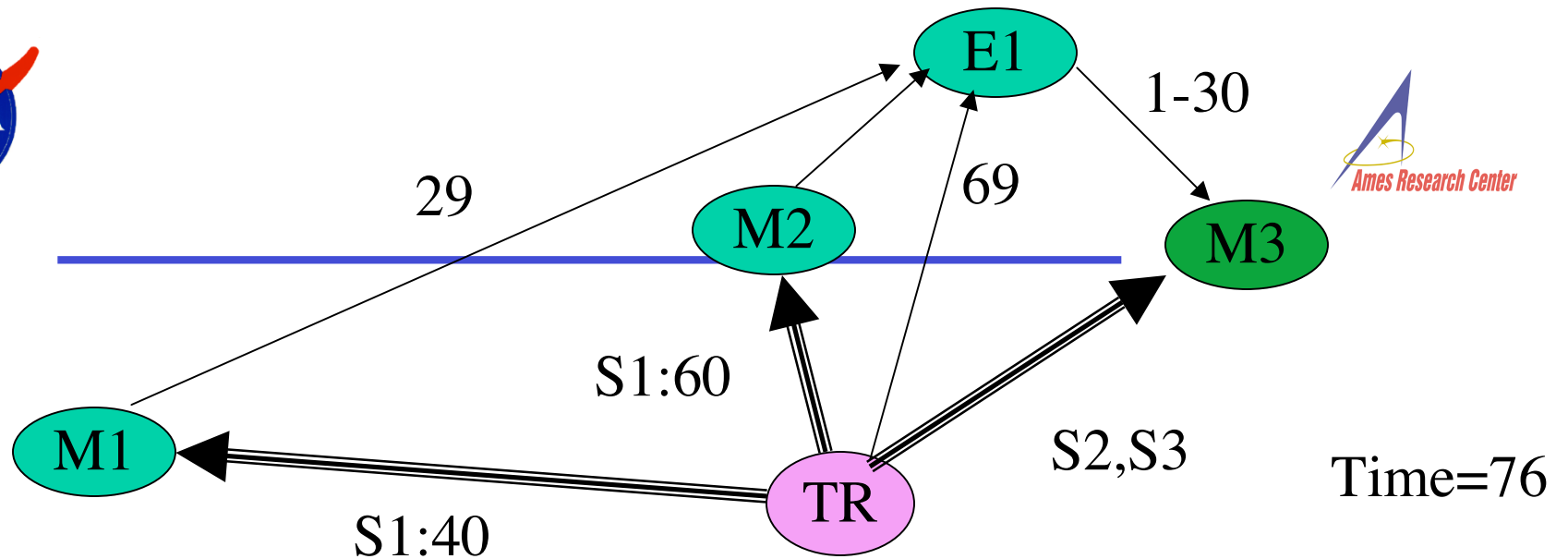
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M3	S2	50	<u>Timed Out</u>
M3	S3	100	<u>Closed (user)</u>
M3	S3	120	<u>Out of range</u>

Observation Request Table



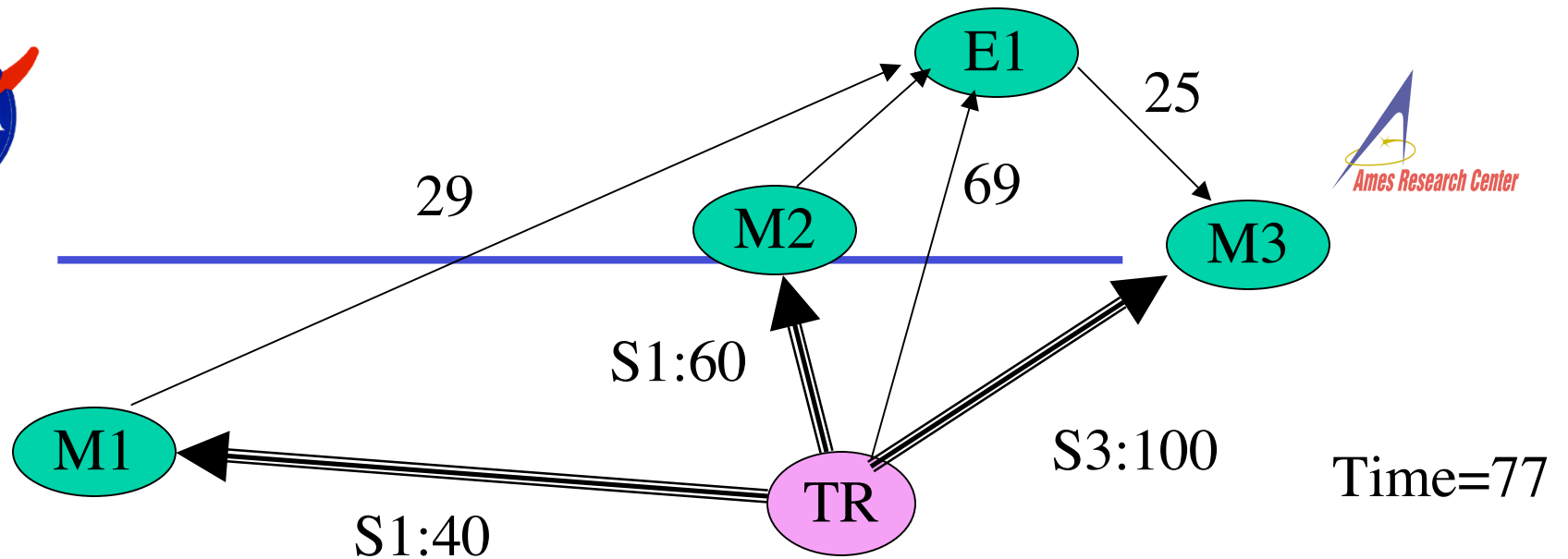
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M3	S3	100	<u>open(user)</u>
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Observation Request Table



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M3	S3	100	<u>Submitted</u>
M3	S3	120	<u>Out of range</u>

Observation Request Table



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Observation Request Table